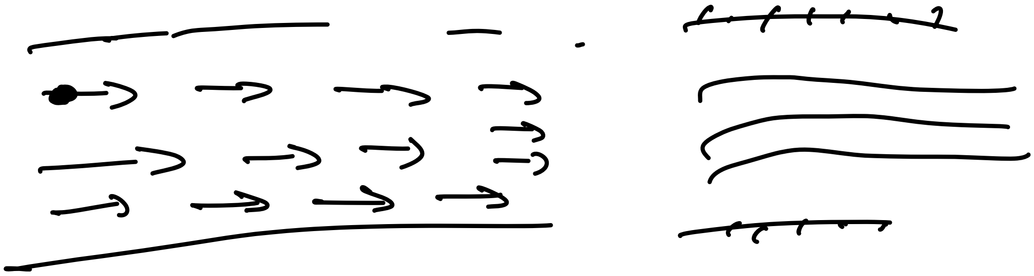
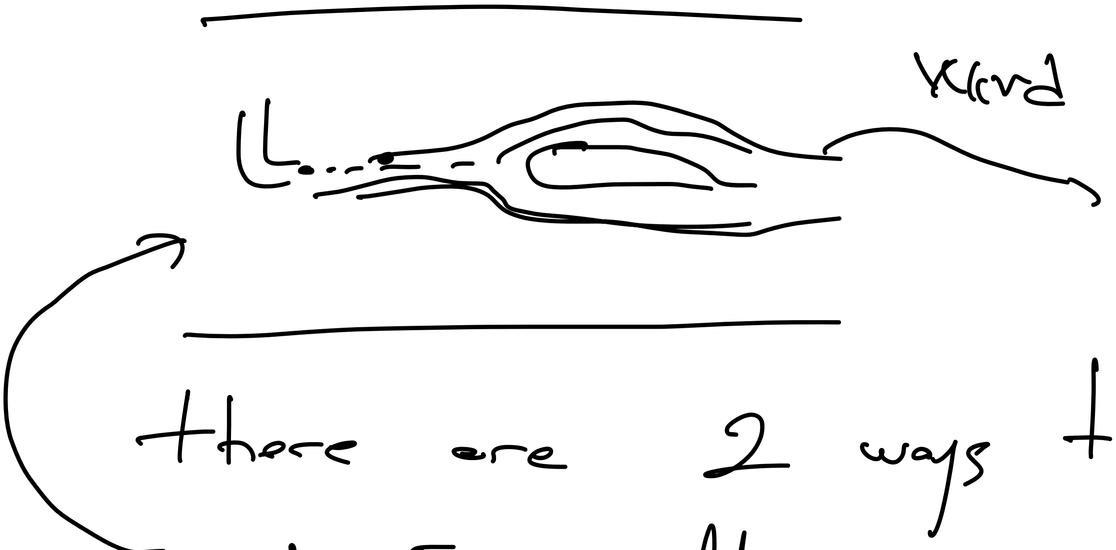
Flow Pattern and Flow Visualization

at CH #4

* CFD, Velocity analysis



wind turb



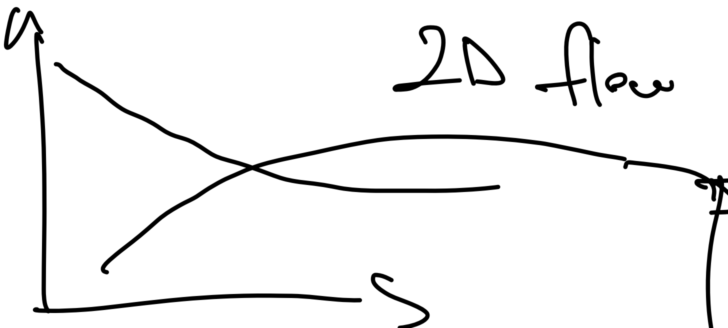
there are 2 ways to visualization

1- Experimentally

2- Numerical → CFD

→ find equation of patter

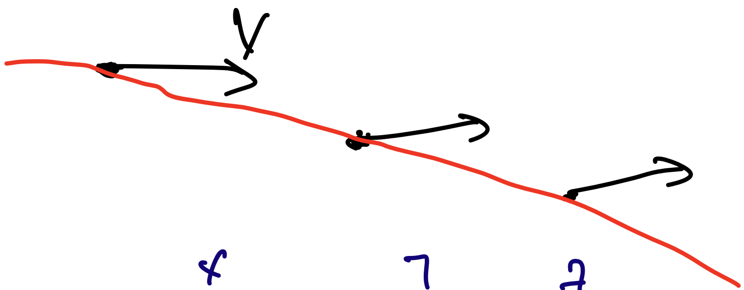
2D flow

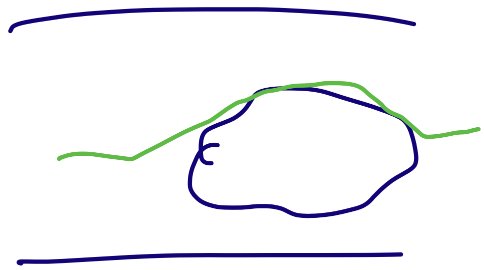


$$\boxed{y = ax^2 + b \ldots}$$

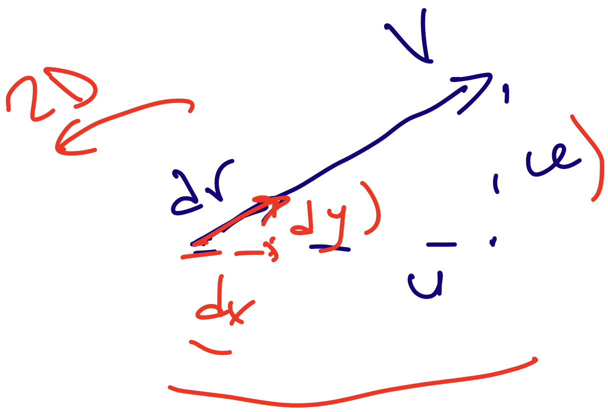
1* Streamline

is a curve that everywhere tangent to the instantaneous local velocity vector.





$$\overset{x}{\vec{V}} = u\,\hat{i} + \overset{y}{v\,\hat{j}} + \overset{z}{w\,\hat{k}}$$

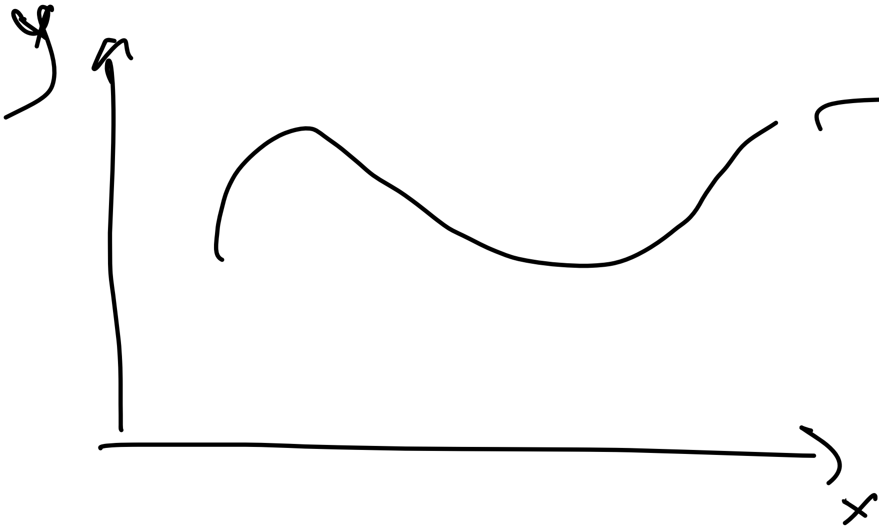


$$\frac{dr}{V} = \frac{dx}{u} = \frac{dy}{v} = \frac{dz}{w}$$

$$\boxed{\frac{dy}{dx} = \frac{v}{u}}$$ – streamline in x-y plane

Ex: a $\vec{V} = (u, v) = (\underbrace{0.5 + 0.8x}_{u})\,\hat{i} + (\underbrace{1.5 - 0.8y}_{v})\,\hat{j}$

plot several streamline in the right half of flow. $x > 0$



$y' = \dots$

$=$

$$\frac{dy}{dx} = \frac{v}{u}, \qquad \frac{dy}{v} = \frac{dx}{u}$$

$$\Rightarrow \frac{dy}{1.5-0.8y} = \frac{dx}{0.5+0.8x} \Rightarrow \int \frac{dy}{1.5-0.8y} - \int \frac{dx}{0.5+0.8x} = 0$$

$$\int \frac{dx}{a+bx} = \frac{1}{b} \cdot \ln(a+bx)$$

$y_i = ?$

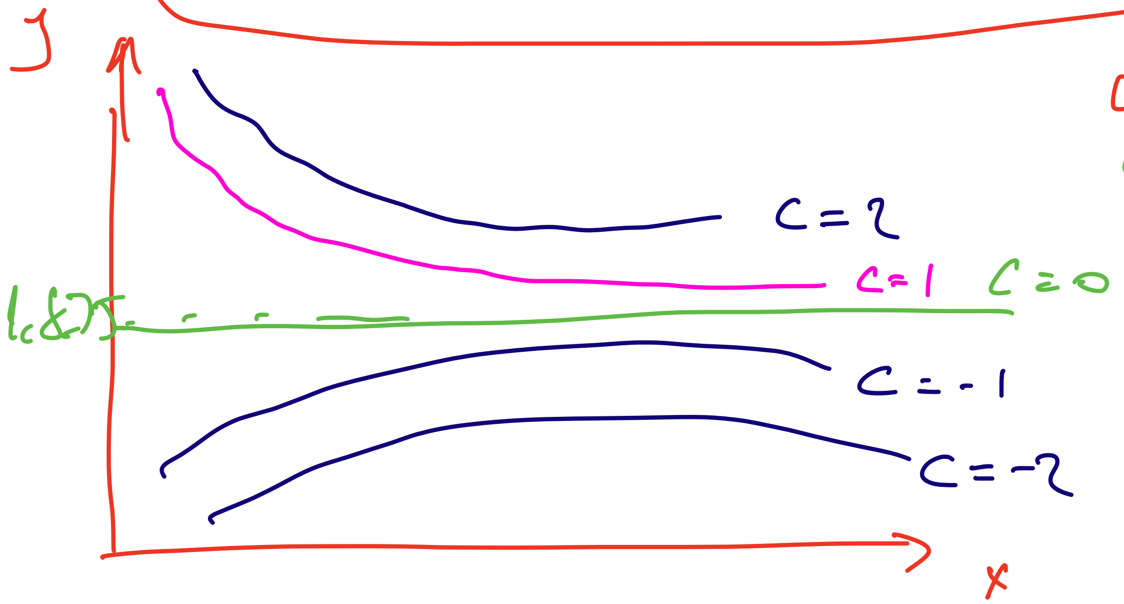
$$-\cancel{\frac{1}{0.8}} \ln(1.5-0.8y) - \cancel{\frac{1}{0.8}} \cdot \ln(0.5+0.8x) = 0$$

$$= -\cancel{\frac{1}{0.8}} \ln C$$

$$\int (\;) = 0$$

$$\ln\left((1.5-0.8y)\cdot(0.5+0.8x)\right)=\ln c$$

$$\boxed{y=\frac{c}{0.8(0.5+0.8x)}+1.875}$$

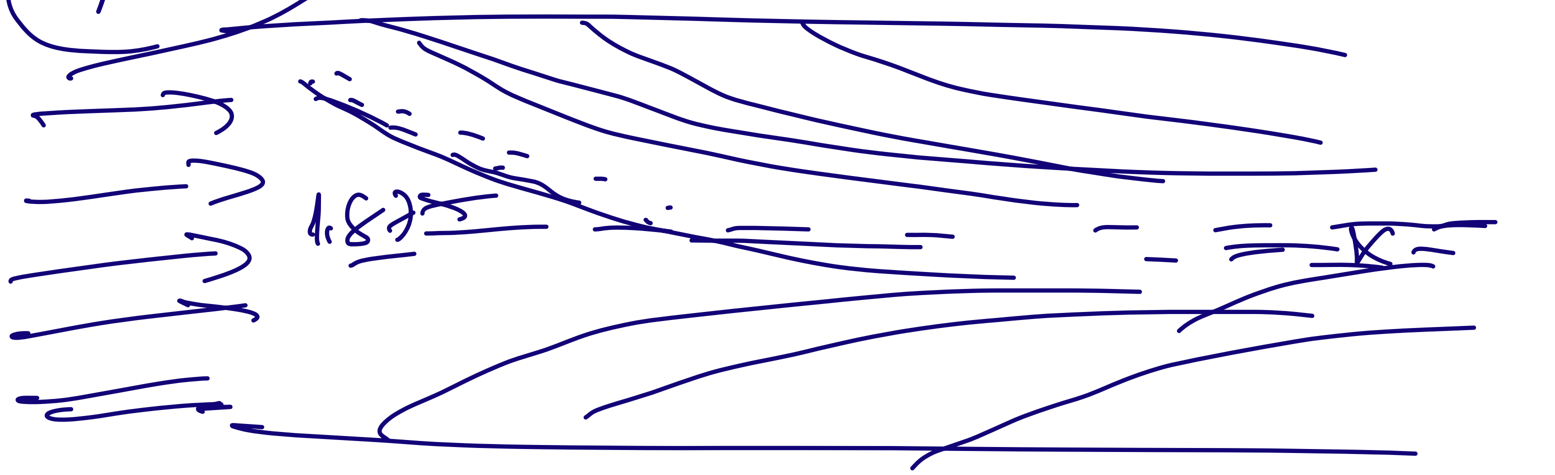


$c = 0.001$ (1.00)

$\vec{V} = ?$

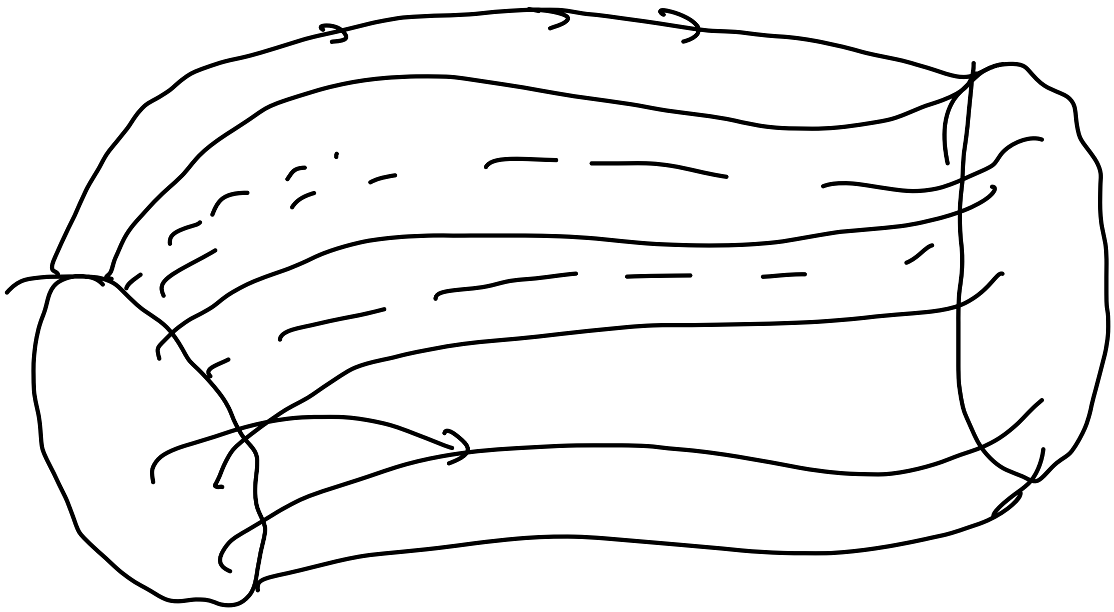
$$\frac{dx}{u}=\frac{dy}{v}$$

Ans)



2 * Streamtube

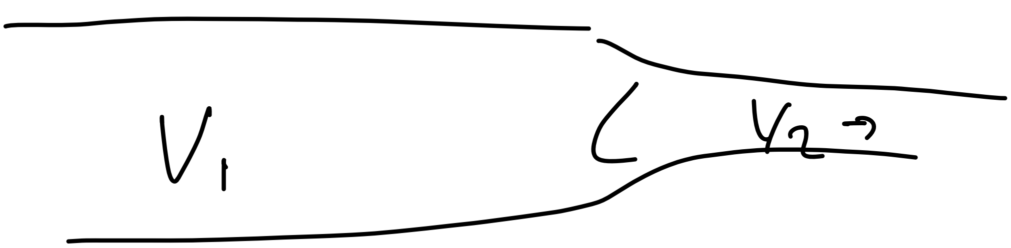
consist of a bundle of streamlines much like a communication cable consist of a bundled fibre



For steady flow : streamtube will not change

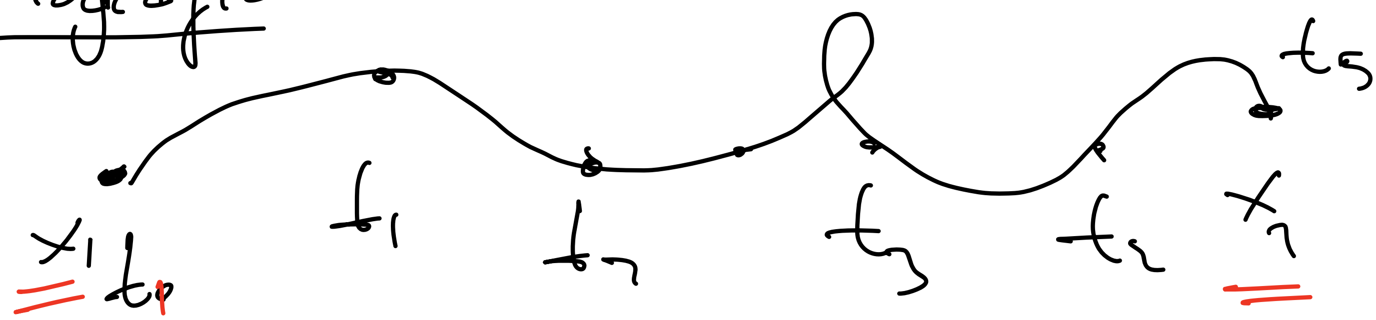
For unsteady flow : streamline or streamtube may change.

Mass flow rate remain constant



3- Pathline is the actual path traveled by individual fluid particle

Lagrangian



$$\vec{V} = \frac{d\vec{X}}{dt} \Rightarrow \int_{x_1}^{x_2} dx = \int_{t_0}^{t_f} V \cdot dt$$

$$X_2 - X_1 = \int_{t_0}^{t_f} V \cdot dt = V(t_f - t_0)$$

x: $x - x_0 = \int_t^{t_f} u\,dt \rightarrow$

y: $y - y_0 = \int_t^{t_f} v\,dt$

z: $z - z_0 = \int_t^{t_f} w\,dt$

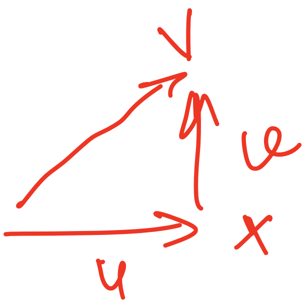
Ex: A fluid flow has a velocity equation vector (2D)

$$\vec{V} = \overbrace{-8x}^{u}\,\hat{i} + \overbrace{4}^{v}\,\hat{j} \qquad y = ax\cdots$$

If at time $= 0$, the fluid particle is at point $(1, 2)$, draw the pathline of fluid particles.

$u = -8x$

$v = 4$



1) $u = \dfrac{dx}{dt} = -8x$

$$\int \frac{dx}{x} = -8\int dt$$

$$\ln x = -8t + C$$

Boundary $t = 0$, $x_0 = 1$, $y_0 = 2$

$$\ln 1 = -8.(0) + C$$

$$C = \ln 1 = 0$$

$$\boxed{\ln x = -8t}$$

2/ $v = \frac{dy}{dt} = 4 \Rightarrow \int dy = 4\int dt$

$$y = 4t + \underline{\underline{c}}$$

B.C $t=0$, $x=1$, $y=2$

$$2 = 4.(0) + c$$

$$\underline{c = 2}$$

$$\boxed{y = 4t + 2}$$

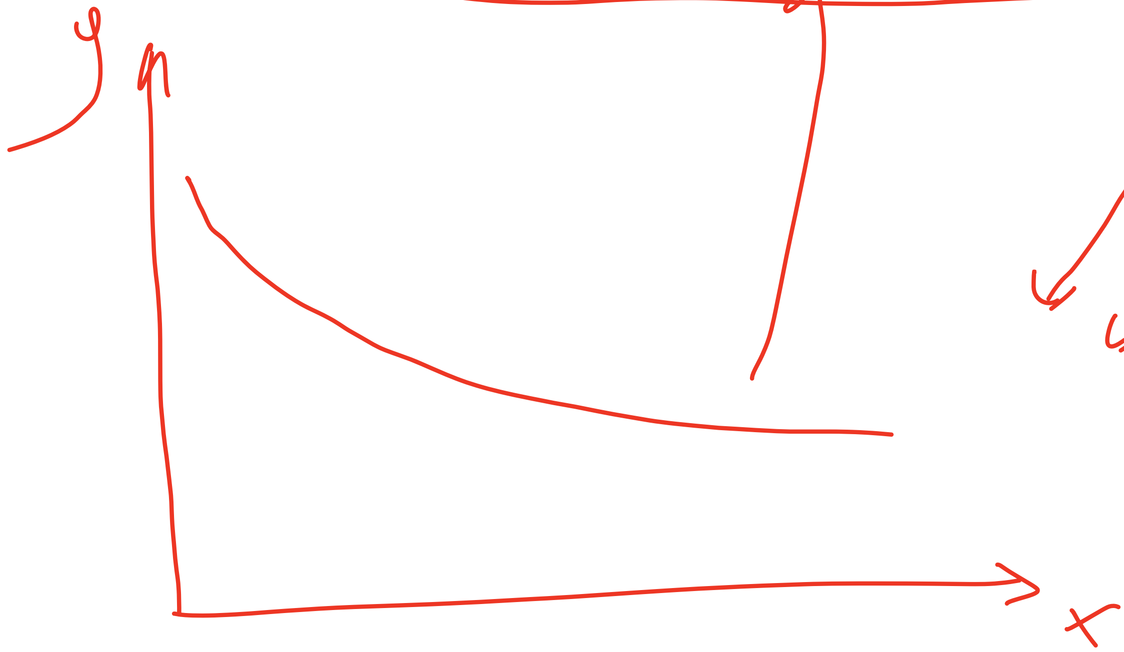
$$\ln x = -8t$$

$$y = 4t + 2 \longrightarrow t = \frac{y-2}{4}$$

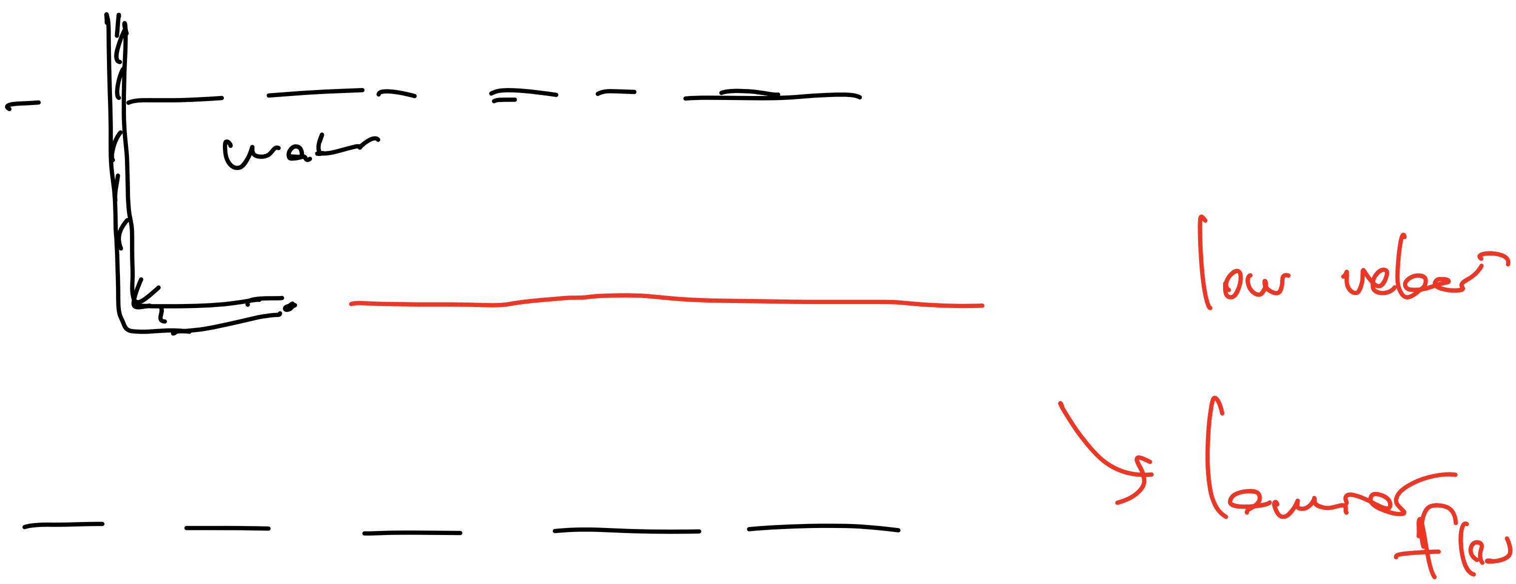
$$\ln x = -8\left(\frac{y-2}{4}\right)$$

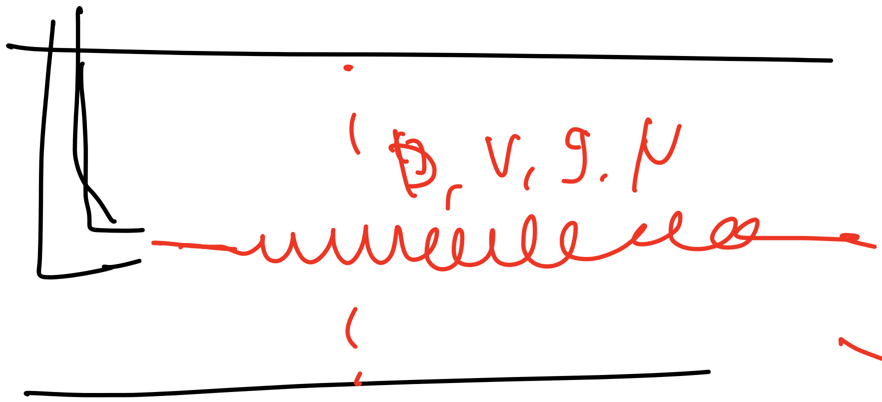
$$\ln x = 4 - \underline{\underline{2y}}$$

$$\boxed{y = 2 - \tfrac{1}{2}\ln x}$$



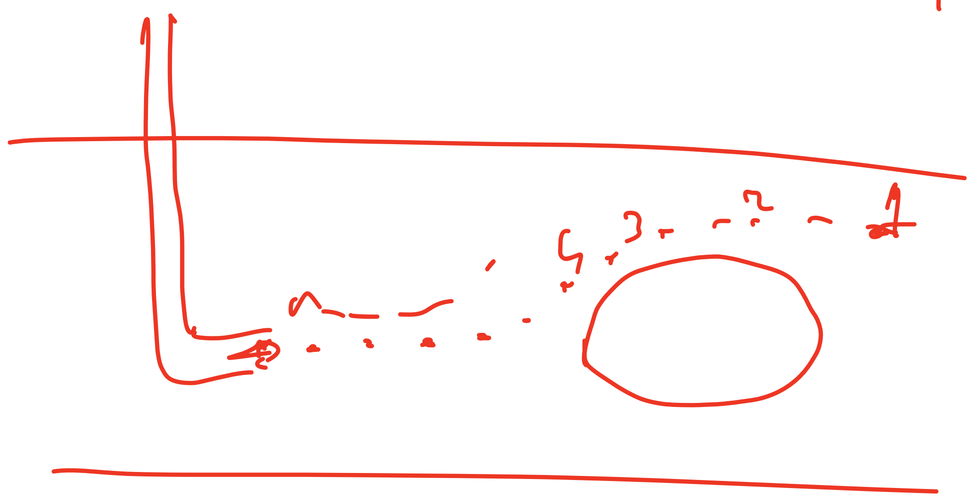
4. <u>Streakline</u> is the most common flow pattern generate in a physical experiment.



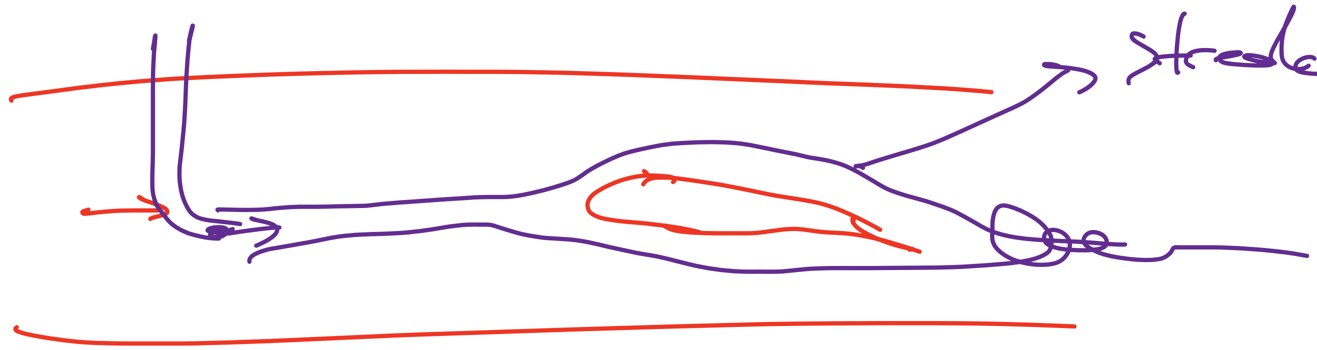


high velocity → turbulent flow

$$Re = \frac{\rho . V . D}{\mu}$$

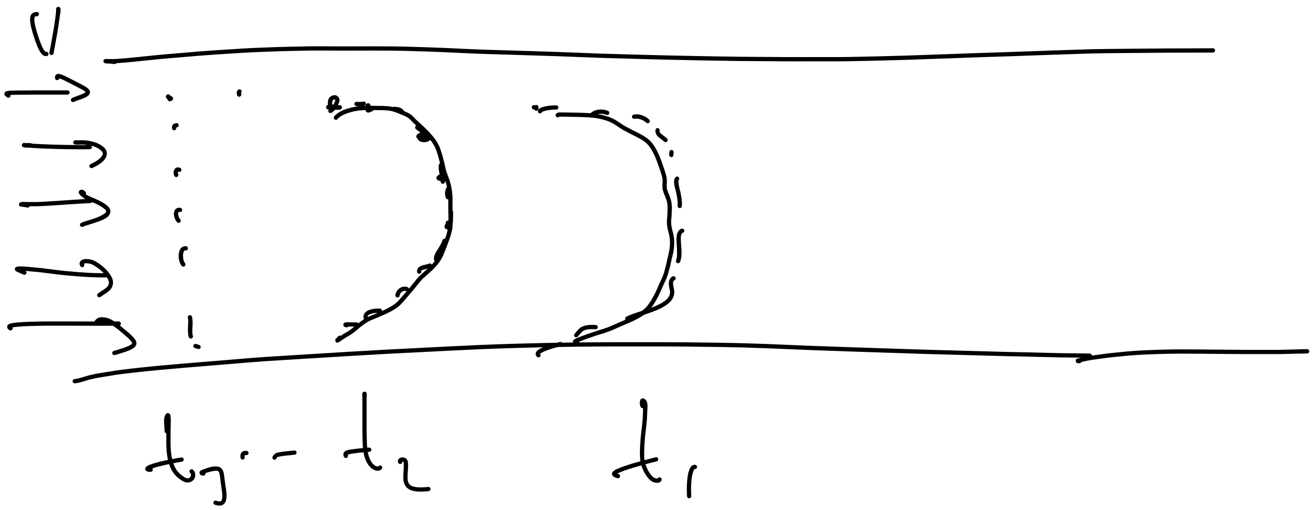


→ liquid



→ streakline

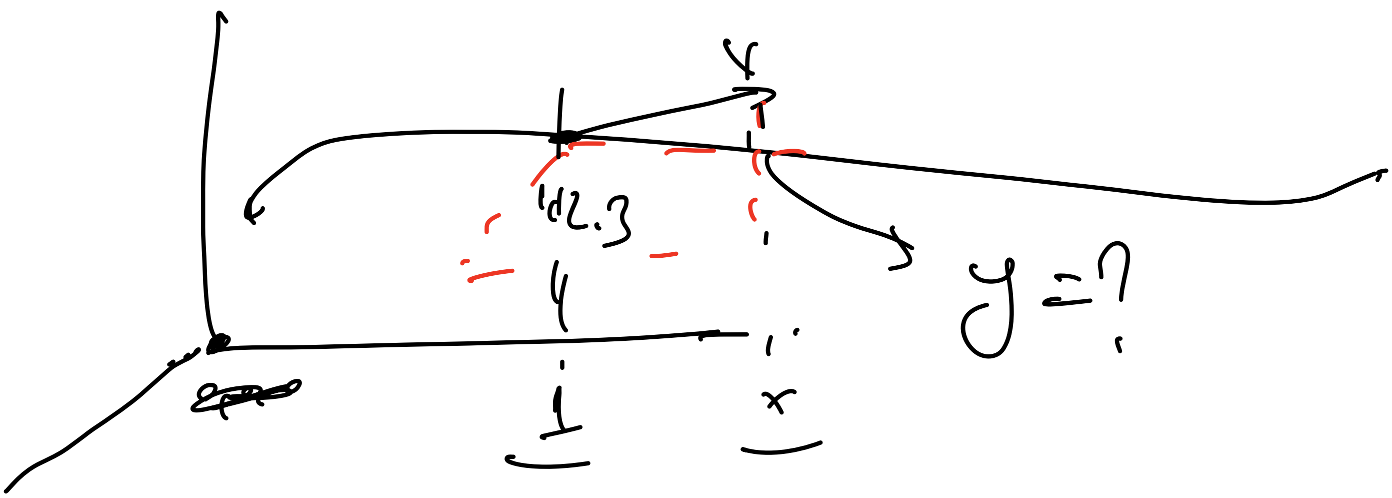
5- Timeline is a set of adjacent fluid particle that were marked at the same instant time



Ex: The velocity of a flow is described by → 3D flow

$$\vec{V} = 4x\vec{i} + (5y+3)\vec{j} + 3t^2\vec{k}$$

what is the pathline of a particle at location (1, 2, 3 m) at time t=1s



$$u = \frac{dx}{dt} \quad , \quad v = \frac{dy}{dt} \quad \omega = \frac{dz}{dt}$$

1/ $u = \frac{dx}{dt} = 4x \Rightarrow \int_1^x \frac{dx}{x} = 4\int_1^t dt \Rightarrow \ln x \Big|_1^x = 4t\Big|_1^t$

$\frac{x}{\text{B.C} \rightarrow 1 - x}$

$$\ln x - \ln 1 = 4 \cdot (t-1)$$

$$\boxed{\ln x = 4(t-1)}$$

2/ $v = \frac{dy}{dt} = 5y+3 \Rightarrow \int_2^y \frac{dy}{5y+3} = \int_1^t dt$

$$\frac{1}{5} \cdot \ln(5y+3)\Big|_1^y = t\Big|_1^t$$

$$\frac{1}{5} \cdot \left(\ln(5y+3) - \ln(5+3)\right) = t-1$$

$$\frac{1}{5} \cdot \ln\left(\frac{5y+3}{8}\right) = t-1$$

$$\boxed{\ln\left(\frac{5y+3}{8}\right) = 5(t-1)} \;*$$

3/

$$w = \frac{dz}{dt} = 3t^2 \Rightarrow \int_3^z dz = 3\int_1^t t^2\,dt$$

$$z\Big|_3^z = \cancel{3}\cdot\frac{t^3}{\cancel{3}}\Big|_1^t$$

$$z-3 = t^3-1$$

$$\boxed{z = t^3+2} \;*$$

$$\ln x = 4(t-1)$$

$$+\quad \ln\left(\frac{5y+3}{8}\right) = 5(t-1)$$

$$\underline{\ln} x + \underline{\ln}\left(\frac{5y+3}{8}\right) = 9\underline{\underline{t}}-9$$

$$t = \frac{9 + \ln\left(\frac{5yx+3x}{8}\right)}{9}$$

$$t = 1 + \frac{\ln}{9} \cdot \left(\frac{5yx+3x}{8}\right)$$

$\uparrow$

$$z = t^3 + 2$$

$$z = \left(1 + \frac{\ln}{9} \cdot \left(\frac{5xy+3x}{8}\right)\right)^3 + 2$$

3D $\quad z = f(x, y)$

If 2D = $\quad y = f(x)$